THE GEOLOGY OF THE CANOBOLAS MOUNTAINS.

By C. A. Sussmilch, F.G.S., and H. I. Jensen, D.Sc.

(Plates vii.-ix.)

A. General Geology and Physiography.

General Geology and Physiography.

i. Introduction.

The Canobolas, or Canoblas, are an isolated group of mountains, about seven miles to the south.east of the town of Orange, N.S.W., and lie at the junction of the three Counties of Bathurst, Wellington, and Ashburnham. Rising about 1600 feet above the level of the surrounding tableland, they form a conspicuous feature of the landscape, particularly when viewed from the west. Situated, as they are, so close to the main Western Railway line and in the neighbourhood of such a large town as Orange, it is surprising that they have received so little attention from geologists in the past.

In 1878, the late Mr. C. S. Wilkinson (then Government Geologist) visited the Canobolas, and came to the conclusion that the "Old Man Canobolas" had at one time formed a point of volcanic eruption on a somewhat grand scale.

In 1890, Prof. T. W. E. David visited the Old Man Canobolas, and subsequently contributed a brief note to the Proceedings of

this Society,* in which he referred particularly to the occurrence of andesitic lavas on this mountain. In 1891, the Rev. J. M. Curran, in a paper read before the Royal Society of New South Wales,† described several rocks from this area, including porphyritic basalts from German's Hill, and fine-grained basalts from the Orange Racecourse. The German's Hill rocks were evidently andesites.

In December, 1901, one of us (C. A. Süssmilch) began a geological survey of the area in conjunction with the Rev. J. M. Curran. A considerable amount of field-work was then done, but the work was subsequently dropped. A re examination, some years later, of the material which had been collected, together with subsequent visits to the Canobolas by one of us (C.A.S.) showed that a resurvey was desirable. This has now been done, and although the rough geological map which resulted from the previous investigation forms the basis of the present survey, the field-work has been done practically *de novo*.

ii. Petrography.

The rocks of this area may be classified as follows :—

Tertiary.	1. Diatomaceous earth. 2. Tuffs. 3. Lavas—Comendites, Trachytes, Andesites, and Basalt.
Palæozoic.	4.(?)Carboniferous—Augite-Porphyrite (intrusive). 5. Devonian—Shales, Sandstones, Quartzites and Conglomerates. 6. Silurian—Slates, Limestones, Rhyolite, and Rhyolite Tuff. 7. Ordovician—Graptolite Slates.

Ordovician.—Graptolite slates occur over a small area near Cadia, a few miles to the south of the Canobolas. This area has not been included in the accompanying map.

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* Note on the "Occurrence of Andesitic Lavas at the Canoblas, near Orange." These Proceedings, Second Series, Vol. v., p.426, 1890.

† A Contribution to the Microscopic Structure of some Australian Rocks. Journ. Proc. Royal Soc. of New South Wales, Vol. xxv., pp.198-204, 1891.

Silurian and Devonian.—That portion of these formations which occurs immediately to the west of this area, has been already described by one of us.‡ In the immediate neighbourhood of Orange, numerous outcrops of slates occur, which are well shown in the cuttings along the Forbes-Molong Railway line. No fossils have been found in these slates, but they are probably of Silurian age. A small outcrop of Silurian limestone occurs on the Canomodine Creek, in the south-western part of the area. All the Palæozoic strata have been subjected to considerable folding, and have been subsequently much denuded. As some of the fossils from this district had not been determined and described when the description of the formations in which they occur was printed, and the names of some have been altered, a corrected list is here included.

List of Silurian Fossils from the Canobolas District.

ACTINOZOA.

- *Halysites lithostrotonoides.*
- *australis.*
- *pycnoblastoides.*
- *Süssmilchii.*
- *cratus.*
- *peristephesicus.*
- *Mucophyllum crateroides.*
- *Arachnophyllum epistomoides.*
- *Mictocystis endophylloides.*
- *Tryplasma liliiformis.*
- *columnaris.*
- *princeps.*
- *Favosites gothlandica.*
- *Heliolites.*
- *Cyathophyllum.*
- *Claudopora* sp.ind.
- *Pachypora* sp.ind.
- *Zaphrentis* sp.ind.

‡ Süssmilch, C. A., F.G.S., Note on the Silurian and Devonian Rocks occurring to the west of the Canobolas Mountains, near Orange. N. S.W. Journ. Proc. Royal Soc. of New South Wales, xl., p.130, 1906 [1907].

Spongida.	*Astylospongia.*
Trilobita.	*Bronteus* sp.ind.
	Phacops sp.ind.
Brachiopoda.	*Conchidium* (*Pentamerus*) *Knightii* var. *stricta.*
	,, ,, *Etheridgii.*
	Anoplotheca(?) *australis.*
	Camarotœchia(?) *Süssmilchii.*
	Conocardium Davidis.
	Orthisina(?).
Crinoidea.	Crinoid stems.

Carboniferous(?).—Extensive intrusions of augite-porphyrite (diabase-porphyry) occur, intruding the Silurian slates in the northern part of the area. These are well exposed along the Forbes Road, and in the cuttings of the Forbes-Molong Railway line. These intrusions possibly took place during the Carboniferous Period.

Tertiary.—(A) Volcanic. These are classified as follows:—

(*a*) Leucocratic Trachytes including Comendites, Pantellarites, light-coloured Arfvedsonite-Trachytes, etc., with their corresponding dyke-rocks. They are all typically light-coloured, and more or less acidic in composition.

(*b*) Melanocratic Trachytes, including Phonolitic Trachytes, Trachy-Andesites, with their corresponding dyke-rocks and tuffs. These are typically darker in colour than the previous group, and some of them might easily be mistaken for andesites in the hand-specimens.

(*c*) Andesites, mostly porphyritic, and inclined to basic in composition.

(*d*) Olivine-Basalts.

(B) *Diatomaceous Earth.*—One deposit was observed in the Parish of Bowan, near the Cargo Road. The mode of occurrence was somewhat obscure, but it appeared to lie below, and therefore to be older than the Andesites.

The Diatoms belong largely to the genus *Melosira*, while sponge-spicules (*Spongilla*) are also abundant.

iii. Physiography and Topography.

These mountains are situated on that portion of the western tableland which forms the divide between the watersheds of the Lachlan and Macquarie Rivers. The tableland has a general altitude of about 3000 feet, and is a continuation of one of the Blue Mountain peneplains described by Mr. E. C. Andrews.* In his first description he refers to it as the Lithgow Plain, but subsequently called it the Blue Mountain Plain.† The earlier name is too local for such an extensive physiographical feature, and, in our opinion, it would be preferable to call it the Orange-Blue Mountain Plain. Between the Canobolas and the Blue Mountains numerous residuals of an older peneplain occur in the form of long ridges and isolated hills. These appear to reach a general altitude of about 3600 feet, and would correspond to the second level in the Blue Mountains referred to by Mr. Andrews, and which he called the Blue Mountain Plain. As this name has now been taken for the lower level (3000 feet level), we would suggest the name of the Clarence Plain for this level.

Standing on top of the Canobolas and looking eastward, one can see several isolated and apparently flat-topped residuals of a still higher level, which appear to exceed 4000 feet in altitude. These probably belong to Mr. Andrews' Jenolan Plain.

The 3000 feet tableland (Orange-Blue Mountain Plain), which in this district has been cut out of the folded Silurian and Devonian strata, is intersected in all directions by numerous shallow, mature valleys, from 100 to 200 feet deep. The township of Orange lies in one of these mature valleys, and the valleys of the present cañon-cycle head into them.

The Canobolas Mountains proper cover an oval area, which has a maximum diameter of about 12 miles, and extends from the Orange-Forbes Railway line on the north, nearly to Cadia on the south; and from the Great Western Railway on the east, to the

* Records Geol. Survey N. S. Wales, 1904, Vol. vii., Part 4.

† Andrews, B.E., B.A.—An Introduction to the Physical Geography of New South Wales. Published by W. Brooks & Co., Sydney. 1905.

Cargo Road on the west. The highest point is the Old Man Canobolas, which reaches an altitude of 4610 feet. The principal peaks are as follows:—

Old Man Canobolas	...	4610 feet.	
Towac (The Bald Knob)...		4500 ,,	
Young Man Canobolas	...	4400 ,,	
The Pinnacle ..	...	4050 ,,	
The Bald Hills (three)	...	4000 ,,	(about).
Johnston's Pinnacle	...	3850 ,,	
Watt's Pinnacle ...	...	3810 ,,	

The Bald Hills, Towac, and the Old Man Canobolas lie on a definite north and south line, while the other peaks stand more or less promiscuously to the east of this line.

To the west of this line the tableland is much lower. At Molong, for example, the altitude of the peneplain is only about 2000 feet. It is quite possible, therefore, that an important fault may occur here, separating the Orange portion of the uplifted peneplain from that part immediately to the west.

That portion of these mountains which reaches above the 3000 feet level, consists entirely of volcanic rocks, lavas and tuffs, piled up around several different volcanic vents. No distinct crater rings remain. We have, then, an approximately level platform of denuded Silurian and Devonian rocks, 3000 feet high, upon which has been piled a series of lavas and tuffs to a maximum height of 1600 feet above this level. These are, therefore, essentially mountains of accumulation. The earlier lavas (comendites, trachytes and andesites) have not been found below the 3000 feet level, but the later basalts have flowed into and, in some cases, filled the mature valleys on top of the tableland. In the mountains the streams are all consequent streams, flowing by direct courses to the tableland; and in most cases they have cut fairly deep gorges into the volcanic rocks. Those flowing to the north and east join the Macquarie River, those to the south and west eventually join the Lachlan.

iv. Descriptive Geology.

Most visitors to the Canobolas travel by the Cargo Road as far as German's Hill, and then turn off on to a branch road to the south, which leads to the top of the Old Man Canobolas. From a tourist's point of view this is an excellent trip, as, from the top of the Old Man can be seen one of the most extensive views in New South Wales. From a geologist's point of view, however, this is the least interesting road to take, as the rock-exposures are not particularly good, nor do we meet with many rock-types. A much more interesting route is that by the Towac Road. This road, soon after leaving Orange, crosses the Molong-Forbes Railway line near the Orange Racecourse, where some good examples of columnar basalt may be seen, both in the railway cuttings and in the adjacent municipal quarries. From here, onward for some miles, the road passes through some of the richest orchard and agricultural land in the district, the rich soils being derived from the decomposition of the andesite lavas. Passing the Canobolas Public School, the andesites give place to trachytes and comendites until the road reaches Summer or Molong Creek, where basalt again makes its appearance. The road now, after passing the Towac School (8 miles from Orange), plunges into a narrow gorge between The Pinnacle and Watt's Pinnacle, for half-a-mile, and then ends in a beautiful valley entirely encircled by hills, and known locally as the "Devil's Hole." We are now in the centre of the most interesting part of the Canobolas Mountains. Immediately to the west stand the Young and Old Man Canobolas; to the south-west are Towac Mountain and the Bald Hills; to the north, Johnston's and Watt's Pinnacles; and to the north-east stands The Pinnacle. This is the centre of the oldest and most acid lavas (comendites, etc.), and surrounding them, in a roughly concentric fashion, in the following order, are the more basic trachytes, with their associated tuffs, then the andesites, and finally the basalts.

1. The Lava-Flows and Tuffs.

(*a*) *The Leucocratic Trachytes.*—These include comendites, pantellarites, and the lighter-coloured trachytes, all of which are

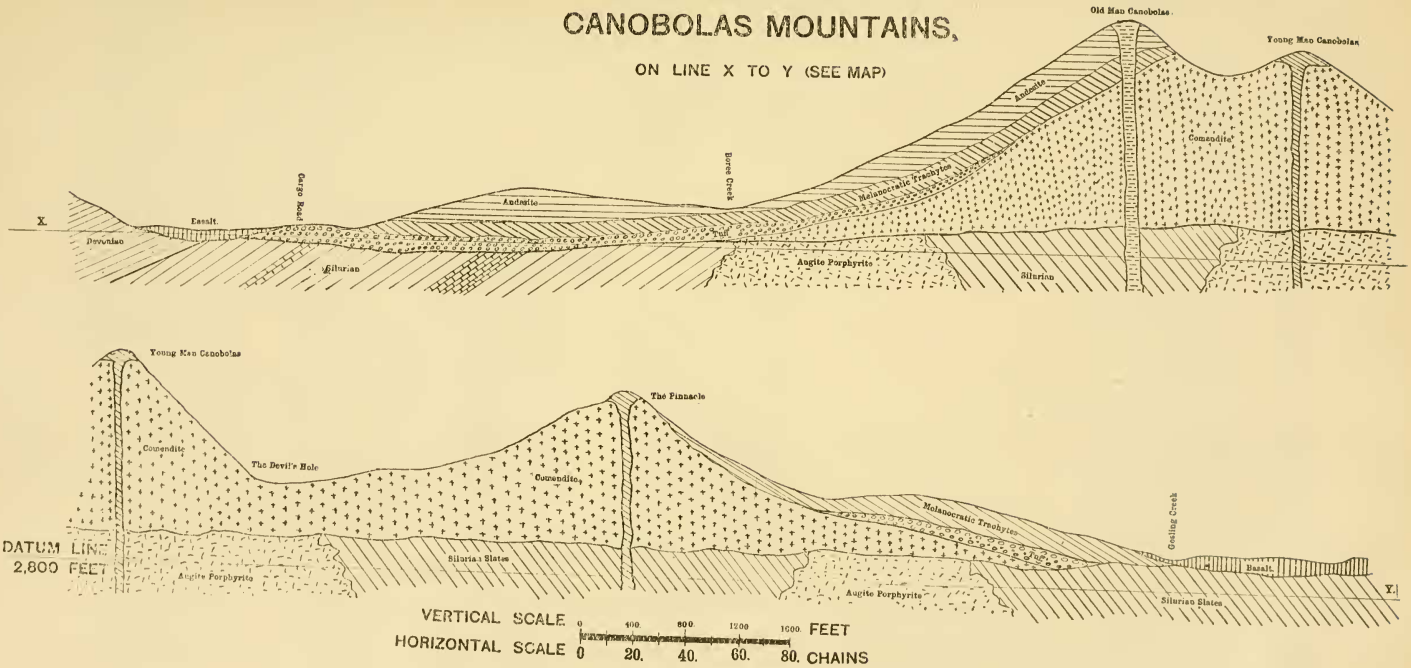
typically white or light bluish-grey in colour, aphanitic in appearance (although glassy examples occur), and may be more or less porphyritic. They are extensively developed in the central area, particularly in and about the Devil's Hole valley, and about the head-waters of the Cadianjulong Creek. The most characteristic of these rocks is the *Orthophyric Arfvedsonite Comendite* (X.583) of which there are large exposures at the base of the Young Man Canobolas, and in the Bald Hills. The former hill, with the exception of the top, is built up almost entirely of this rock; so also are the Bald Hills, with the exception of cappings of the more basic trachytes upon two of them. The centre one of these three hills has a rounded summit, exposing a bare outcrop of this rock, devoid of soil and vegetation, which, with the white colour of the rock, gives it a striking appearance. This rock polishes well, taking on a beautiful honey-yellow colour mottled with dark blue, and makes a handsome ornamental stone. A second type of arfvedsonite-comendite (X.631) although not differing appreciably in composition, differs somewhat in appearance, and has a characteristic bluish-grey colour. This constitutes the bulk of the Pinnacle, and is well exposed all along the east side of the Devil's Hole. On Johnston's Pinnacle massive bold outcrops of light-coloured ægirine-trachyte occur, exhibiting columnar structure.

All of these leucocratic types of trachyte give bare rugged outcrops, and the soil derived from their decomposition, as one would expect from their composition, is very poor in character. Columnar structure is not uncommon. The mode of occurrence of these acid lavas suggests that they were erupted from a number of different vents. Owing to their acid composition they solidified rapidly, and censequently did not travel far, but built up steep lava-cones. These are the oldest of the Canobolas lavas, and, wherever junctions occur, are seen to be overlain by the more basic rocks (see figs.1 and 2).

(*b*) *The Melanocratic Trachytes.*—These differ from the leucocratic types in containing little or no quartz, a relatively large proportion of the ferromagnesian constituent, and are more

SECTION ACROSS THE CANOBOLAS MOUNTAINS,

ON LINE X TO Y (SEE MAP)



alkaline in composition. This gives these rocks a darker colour, some of them appearing andesitic or even basaltic in appearance in the hand-specimen. These characteristics make the mapping of the boundaries between this series and the more basic rocks somewhat uncertain; and, in many places, the boundaries given

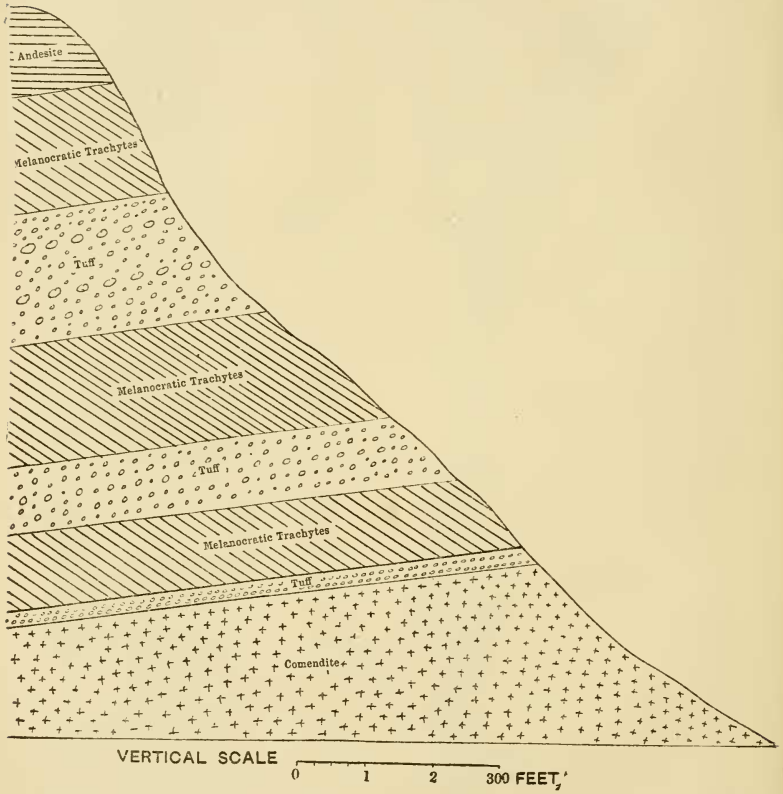


Fig. 1.—Diagrammatic Section from Towac Mountain to The Devil's Hole, showing succession of lavas and tuffs.

in the accompanying map are only approximate. The alkaline trachytes outcrop over a considerably larger area than do the more acid type. They are found capping the comendites of the

Young Man Canobolas, and two of the Bald Hills; they form the bulk of Watt's Pinnacle, and almost entirely encircle the central area of acidic rock. The distribution of these lavas, with their associated tuffs, indicates a central point of eruption, somewhere adjacent to what is now called the Devil's Hole. This valley itself has somewhat the appearance of a huge crater, but is probably a valley of denudation. The plugs of sölvsbergite which occur at the top of the Young Man Canobolas and on The Pinnacle, are the probable vents from which this series was erupted.

All the tuffs so far observed are associated with the melanocratic trachyte-lavas. The following section taken from the divide between the head-waters of Summer Creek and Cadianjulong Creek, immediately south from Plowman's Farm, shows three distinct beds of tuffs.

The lowest bed, which rests directly upon the comendite, is somewhat fine-grained, and contains numerous fragments of

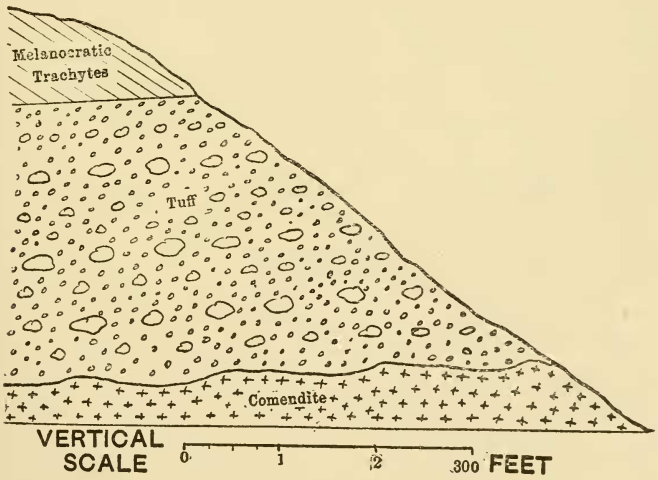


Fig. 2.—Section at Cadianjulong Creek, showing tuffs and lavas.

comendite. The upper beds are much coarser, and contain ejected blocks of all sizes. About 2 miles further south, on the Cadianjulong Creek, a tuff-bed, 340 feet thick, occurs, as shown in the accompanying sketch (fig. 2).

On the Pinnacle Road, about $1\frac{1}{4}$ miles from the summit of The Pinnacle, tuffs occur, containing ejected blocks ranging up to 1 ton, or even more, in weight. A somewhat similar outcrop occurs at Norris's Farm, on the western side of the Canobolas. All these tuffs are essentially trachytic in composition, but contain numerous fragments of the earlier and more acid comendites, etc. The tuff-beds, as far as could be observed, dip away from the central area. They also outcrop on the road leading to the top of the Old Man, but this, and several other small outcrops, have not been shown on the accompanying map. Mr. T. Harvey Johnston, B.Sc., informs us that he found fragments of coniferous wood in these tuffs near German's Hill.

(*c*) *The Andesites.*—These lavas are of a somewhat basic type, and contain numerous phenocrysts of plagioclase, with occasional phenocrysts of augite and olivine. They are sometimes vesicular. A reference to the map will show that they are extensively developed to the west and north of the area dealt with. The boundaries shown on the map are only approximate; firstly, because the area to the west and north-west was not surveyed in detail; and secondly, owing to the frequent difficulty in discriminating between the decomposed outcrops of the more basic trachytes and andesites respectively.

The Old Man Canobolas was the point of eruption from which these lavas were derived, Prof. David, in the note already referred to, gives the following description of the neck or plug on top of this mountain :—" At a point bearing S. 15° W., 78 yards distant from the Trigonometrical Station on top of the 'Old Man Canobla' is, what the author considers to be, the central 'neck' of the volcano, in the shape of a nearly circular mass of coarsely crystalline very dense andesitic lava, rising from four to five feet above the general level, and showing strongly marked oblique lamination, the laminæ dipping in towards the centre of the neck at an angle of from 40° to 60°. The neck is about $\frac{1}{2}$ chain in diameter, and is surrounded by beds of scoriaceous lava to the north and scoriæ to the south. The beds of the former to the north dip northerly at about 15°, and are overlaid by a dense

flow of lava, on the highest point of which the Trigonometrical Station now stands. South of the neck the beds of scoriæ dip first northerly towards the neck, and then qua-qua-versally chiefly from west towards south at an angle of 20° up to 40°, as far as the western edge of the mountain, where the scoriæ pass into a coarse volcanic agglomerate composed chiefly of large pieces of cellular andesitic lava."

The writers of this paper were unfortunate on the day they visited the Old Man Canobolas, in meeting with dense mists and heavy rain, which made a detailed examination impossible. They saw enough, however, to satisfy themselves of the general correctness of Prof. David's views. One of the best outcrops of these andesites can be seen at the Hopetoun Waterfall, where one of the flows is over 100 feet thick; good outcrops also occur in the road-cuttings on the Towac Road, near the Canobolas Public School.

The decomposition of the andesites gives rise to excellent soils for agricultural and fruitgrowing purposes, as evidenced from some of the farms and orchards which occur on the andesite soils along the Towac Road.

(*d*) *The Basalts.*—These are typical compact olivine-basalts, and frequently exhibit columnar structure. An examination of the accompanying map will show that they completely encircle the Canobolas Mountains, and occur at and about the 3000 feet level. Nowhere do they occur on any of the high hills, the highest point to which we succeeded in tracing them being 3300 feet, on Summer Creek (Molong Creek). Their distribution and occurrence suggest that they were poured out from fissures in the sides of the mountains, flowed into and submerged many of the shallow mature valleys of the tableland, and spread out over the tableland-level, extending to many miles beyond the limits of the area mapped.

2. Dykes and Necks.

(*a*) *Dykes.*—These are not abundant. A biotite-trachyte dyke (X.613) outcrops on the saddle between the Old and Young Man

Canobolas; another, consisting of quartz-acmite-trachyte-porphyry (X.691) occurs on Portion 259, Parish of Waldegrave. Lastly, what appears to be a large dyke occurs on the main divide south of the Devil's Hole, and consists of an oligoclase-sölvsbergite (X.688); this outcrops again further to the east on Portion 171, Parish of Waldegrave.

(*b*) *Necks.*—Plugs of sölvsbergite, coarsely porphyritic, occur on top of the Young Man Canobolas (X.686) and near the top of The Pinnacle (X.691). These two plugs, as already mentioned, probably represent the vents from which most of the melanocratic types of trachyte were erupted. The only other plug observed is that already described as occurring on top of the Old Man Canobolas, from which the andesites were erupted.

3 Order of Eruption.

The order of eruption, judging from the field-evidence, was from acidic to basic, as follows :—

1. Comendites, pantellarites, and quartz-trachytes.
2. Trachytes, and phonolitic-trachytes, with abundant tuffs.
3. Andesite, somewhat basic in composition.
4. Olivine melilite basalts.

No great interval of time seems to have elapsed between the eruptions of 1 and 2, and between 2 and 3. But between the eruptions of 3 and 4, a long period of erosion is indicated, showing a long lapse of time after the eruption of the andesite, before the basalts were poured out.

The volcanic history of the district was probably as follows:—

Silurian—submarine eruptions, with the production of acid rhyolites and rhyolite-tuffs.

Devonian—none.

Carboniferous—intrusion of intermediate augite-porphyrites.

Mesozoic—none.

Eocene | *Miocene* }—outpouring of comendites, trachytes and andesites.

Pliocene—fissure-eruptions, with outpouring of basic melilite-basalts.

4. Age of the Volcanic Rocks.

No direct evidence has yet been found as to the age of the alkaline lavas of this district. The oldest fossiliferous strata observed are of Devonian age, and these had been extensively folded and denuded before the lavas were deposited upon them.

The age of the peneplain upon which they rest is also uncertain. Mr. E. C. Andrews, in his published description of this feature in the Blue Mountains, considered that it had been cut out in the Pliocene period, but has since expressed the opinion that it may be considerably older. Until the study of the peneplains of Eastern Australia is carried into the marine Tertiary areas of Victoria, it will be difficult to arrive at any satisfactory conclusion. As already pointed out by one of us (H. I. Jensen),* a remarkable similarity occurs in every way between the alkaline rocks of the Canobolas area, and those of the Warrumbungle and Nandewar areas. In all these areas, also, the lavas have been deposited on top of what are, probably, portions of the same peneplain. There is every reason for believing, therefore, that the eruptions in the three areas were contemporaneous. In the Warrumbungle Mountains, fossil leaves have been obtained from a bed of tuff, near the base of the volcanic series. These have been described by Mr. Henry Deane,† who considers that they may be of Eocene age. This determination, if correct, would relegate the beginning of the volcanic series to the Eocene, and would correspondingly put back the cutting out of the peneplain to the early Eocene, or even Cretaceous. It is questionable as to how much reliance can be placed upon the evidence of a few Tertiary leaves, as to geological age; so that the age, both of the peneplain, and of the volcanic series, must still remain doubtful, but we can assume that it still lies somewhere between the Upper Cretaceous and the Miocene.

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* The Alkaline Petrographical Province of Eastern Australia. Proc. Linn. Soc. N. S. Wales, 1908, p.589.

†Notes on Specimens of Fossil Leaves from the Warrumbungle Mountains. Rec. Geol. Surv. N. S. Wales, Vol. viii., Part 3.

Petrological Descriptions.

The petrology of the Silurian and Devonian rocks to the west of the Canobolas, has already been described by one of us (C. A. Süssmilch,* F.G.S.). The rocks probably underlie the later volcanic series of the Canobolas, but, as they do not outcrop on the surface in the area now under special consideration, no further mention of them will be made here.

The volcanic series is divisible into :—

A. *Leucocratic Trachytes* (including comendites, pantellarites, light-coloured arfvedsonite-trachytes, etc.) and the dyke-rocks corresponding to them.

B. *Melanocratic Trachytes* (including phonolitic trachytes and trachy-andesites), and the corresponding dyke-rocks.

C. *Andesites*, chiefly of an alkaline facies.

D. *Basalts* (with melilite and analcite.)

With the exception of some of the basalts, all the rocks of this volcanic series belong to the alkaline division.

The plan will here be followed of describing a few of the typical rocks of each group in some detail, and appending brief petrological sketches of other varieties belonging to each group.

Volcanic Sequence.—The earliest eruptions gave rise to flows, plugs, necks, and dykes of leucocratic trachyte.

The next eruptions yielded melanocratic trachytes and trachy-andesites, and intrusions of their dyke-equivalents took place. Pyroclastic rocks of this period are common.

The following eruptions gave rise to alkaline andesites, and the basalts were extruded last. The sequence is therefore one of increasing basicity.

It is also a matter of interest that the earliest eruptions were of a very explosive nature, whereas the late eruptions poured out immense quantities of lava in a quiet and peaceful manner.

A. *The Leucocratic Trachytes.*—No.X.608. Field-name, Quartz-Trachyte. Loc.: Cadiangelong Creek.

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* Journ. Proc. Roy. Soc. N. S. Wales, Vol. xl., p.130.

Handspecimen: yellowish-grey rock in which small sanidine phenocrysts can be recognised with the naked eye.

Microscopic Structure—(1) Texture: hypocrystalline, hiatal porphyritic, with trachytic fabric in the fine-grained base. (2)Composition: felspar, the dominant constituent, forms over 80 % of the slide. It is always idiomorphic, and occurs chiefly as Carlsbad twins. The crystals have an orthorhombic aspect, and have the faces $m(110)$, $b(010)$, $c(001)$ and $x(101)$ well developed. Consequently the sections obtained are mostly equant (square, five-sided and six-sided), and some rectangular, elongated in the c direction, or more irregular when cut obliquely. Some crystals twinned on the Baveno-law, and apparently enclosed by the faces $c(001)$, $y(201)$, $z(130)$, and $b(010)$ are also present. Manebach twinning, with c as composition-face, has also been detected. In addition, other complex forms of twinning occur, some approaching the albite-, others the pericline-type, but they show as shadowy bars instead of distinct lamellæ. Twinning of this kind is probable due to an interlamellation of two varieties of felspar. The extinction-angle measured on the edge cb is from 6° to 12° in different crystals. Inclusions consisting of sagenitic rutile, blue amphibole and brown amphibole, occur in the felspar. Cross-cracks parallel to (100) are well developed. From the observed characters it is clear that the felspar has the composition of soda-sanidine, which sometimes becomes microcline-microperthite by the development of complex twinning. The next mineral in order of abundance consists of irregular grains of a deep reddish-brown mineral, pleochroic from wine-red to almost black-opaque. The pleochroism is to some extent masked by high absorption. Cleavage is faint. This mineral tends to form a pœcilitic intergrowth with felspar, and the blue soda-amphibole clusters round it, the brown mineral merging into the blue by imperceptible gradations. The blue hornblende appears to be riebeckite, and the brown is probably kataphorite. The two together form 7-8 % of the area of the slide. Glass and other isotropic materials (including isotropic chalcedony and opal) form about 10 % of the area. A few allotriomorphic quartz-grains

occur, and also some grains of a yellow isotropic mineral with high refractive index, which tend to gather round the brown amphibole. This yellow mineral is probably perofskite.

3. Order of consolidation.

Rutile ————
Kataphorite and
Cossyrite(?)————————
Riebeckite ————————————————
Perofskite(?) ————————
Anorthoclase ————————
(1st generation)
Do.(later generations) ————————————
Quartz ————
Glass ————

4. Name : Trachytic Kataphorite-Riebeckite-Comendite.

5. Magmatic name: Kallerudose (see Analysis vi., p.191). This magma is common in the Glass House Mountains.

No.X.583. Quartz-Trachyte. Loc.: Canobolas.

Microscopic Texture : fine-grained, holocrystalline, with an hypidiomorphic granular fabric approaching *orthophyric*.

Constituents : felspar, arfvedsonite, ægirine-augite, quartz, and eudialyte(?). The felspar consists of corroded, anorthoclase phenocrysts exhibiting shadowy extinction, and fine sanidine microlites with an extinction of 8°-10°. Some are nephilinitoid, and some prismatic in habit. The amphibole consists of mossy poikilitic aggregates, which exhibit the pleochroism of arfvedsonite (viz., $\mathfrak{c}$ deep blue-black, $\mathfrak{b}$ lavender, $\mathfrak{a}$ pale greenish-yellow), and of ragged grains which approach riebeckite closely in colour and pleochroism, but have a higher extinction-angle (about 10°). The absorption of the typical poikilitic arfvedsonite is $\mathfrak{c}>\mathfrak{b}>\mathfrak{a}$, and the extinction $(\mathfrak{a} : c) = 14°$. Skeleton crystals of brown pleochroic cossyrite occur sparingly. Very minute ægirine-augite grains and rods are abundant interstitially. A yellow, feebly pleochroic mineral occurs; it changes from yellow to a faint peach-blossom tint on rotating the stage, and is resolved between crossed nicols into zones, some of which are isotropic, others doubly refracting.

It frequently forms the nucleus of an amphibole group. Possibly it is eudialyte. Quartz is an abundant interstitial constituent in allotriomorphic grains.

Order of consolidation :

1. Eudialyte(?) ——
2. Arfvedsonite ————
3. Felspar ————————
4. Ægirine-Augite ———
5. Quartz ———

Name : Orthophyric Arfvedsonite-Comendite.

Magmatic name ; Kallerudose (Analysis vii., p. 191).

No.X.625. Soda-Trachyte. Loc.: Portion 92, Parish Towac.

Handspecimen : bluish-grey compact rock.

Texture : hypocrystalline with trachytic fabric.

Composition : the phenocrysts consist of soda-sanidine. The base consists essentially of felspar microlites. In addition, the rock contains small amounts of ægirite, wöhlerite, riebeckite, magnetite, primary hæmatite, and isotropic residuum. A little secondary hæmatite and magnetite are also present.

Name : Wöhlerite-bearing Soda-Trachyte.

No.X.635. Soda-Trachyte. Loc.: Portion 92, Parish Towac.

Microscopic Texture : porphyritic, hiatal, perpatic. Hyalopilitic to trachytic base, which varies in grain-size, from cryptocrystalline (or hypocrystalline) to microcrystalline.

Composition : felspar is the main constituent. Magnetite, laavenite and glass are present in minor amount. The felspar phenocrysts are composed of cryptoperthite. That of the base consists of sanidine laths. In many parts of the base we get minute needles of laavenite(?), with nearly straight extinction, and parting parallel to the prism-zone. They are optically negative, and have the pleochroism a=light wine-yellow, b= greenish-yellow, c=brownish-yellow, and absorption $c>b>a$. The magnetite is rounded by corrosion. The glass is interstitial. Nepheline is suspected in the base.

Name : Hypocrystalline, Laavenite-bearing Soda-Trachyte.

Note: this specimen and the preceding, X.625, are clastic fragments out of the tuff-beds.

No.X.638. Vesicular, bluish-grey Trachyte. Loc.: Forbes Road, near Molong Road.

This rock varies in grain-size from cryptocrystalline to microcrystalline, and has pilotaxitic fabric. Its components are felspar, ægirine, arfvedsonite, and laavenite(!).

No.X.631. Compact, bluish-grey Trachyte. Loc.: east side of Plowman's Farm.

Texture: holocrystalline, porphyritic, perpatic, with very fine even-grained trachytic base.

Composition: the dominant constituent is felspar. As minor, yet essential, constituents, there are quartz, arfvedsonite, and barkevicite. The felspar phenocrysts consist of cryptoperthitic anorthoclase of prismatic habit. The felspar of the base consists of lath-shaped microlites of sanidine (soda-rich?). The amphibole in poikilitic aggregates is pleochroic in brownish-yellow, greenish-blue, and blue-black. The brownish tints come mainly from the edge of each grain, and appear to be due to a rim of barkevicite surrounding each arfvedsonite grain. Secondary leucoxene and quartz are present.

Name: Trachytic Arfvedsonite-Comendite.

No.X.630. Soda-Trachyte. Loc.: north side of Young Man.

Handspecimen: compact, fine-grained, bluish rock, with a few phaneric crystals.

Texture: holocrystalline, with trachytic fabric in the fine even-grained hase.

Constituents: (a) felspar of two generations, (b) quartz, (c) riebeckite, (d) wöhlerite. The phenocrysts consist of anorthoclase. They are of orthophyric habit, more or less corroded, and show shadowy extinction from ultramicroscopic twinning. They are optically negative and almost uniaxial; $\mathfrak{a}$ lies near the a axis. The felspar of the base consists of lath-shaped sanidine microlites with Carlsbad twinning. Quartz is a rather abundant constituent in the base; it is quite allotriomorphic, and often com-

pletely envelops felspar crystals in an ophitic manner The soda-amphibole occurs as mossy and feathery aggregates of grains, and in minute rods. It has the characteristic properties of riebeckite. As an accessory we have needles of a yellow, highly birefringent but feebly pleochroic mineral, which appears to be wöhlerite.

Name: Riebeckite Wöhlerite(?) Comendite.

No.X.618. Compact whitish Trachyte. Loc.: south side of Johnston's Pinnacle.

This rock resembles the typical Conowrin trachyte of the Glass House Mountains.

Texture: hypocrystalline, hyalopilitic, with stellate (pseudo-spherulitic) arrangement.

Constituents: microlites of soda-sanidine; interstitial masses of colourless glass; stout rods of ægirine-augite, strongly pleochroic in bluish-green, olive-green, and yellowish-green; chlorite; secondary iron-ores, and occasional corroded magnetite grains.

Name: Hypocrystalline Ægirine-Trachyte.

No.X.611. Aphanitic Trachyte. Loc.: Norris's Paddock, Spring Creek.

Handspecimen: loose, compact specimen out of the tuffs; it has a rhyolitic appearance, being banded through flow-structure.

Texture: hypocrystalline; very fine and even-grained; marked off into stellate groups of minute microlites so as to have a pseudospherulitic (strahlenkörnig) fabric.

Composition; the chief constituents are the felspar (sanidine?) microlites and interstitial glass. The latter has a very low refractive index, and is light grey in colour. Idiomorphic grains of bluish-green ægirine, and small rutile rods occur sparingly. A common accessory is a yellow mineral elongated in the a direction, which coincides with crystallographic b: $Bx_a = a$: b almost coincides with the c axis. These properties, together with the colour and pleochroism, are those of wöhlerite.

Name: Pseudospherulitic Wöhlerite(?) Ali-trachyte.

No.X.613 Biotite-Trachyte. Loc.: a dyke, with glassy selvage, between the Young and Old Man.

Handspecimen: grey, slightly vesicular, with macroscopic phenocrysts of biotite and felspar.

Texture: porphyritic-hiatal; base pseudospherulitic as in X.611.

Composition: the phenocrysts of felspar have the properties of sanidine; the microlites of the base have the same composition; the former are fractured and corroded to a great extent. The biotite is of a deep brown colour, and somewhat corroded. Small flakes of it are included in the felspars. The ægirine-augite extinguishes at 22°. It is light green and weakly pleochroic It occurs only sparingly, as fine idiomorphic phenocrysts, which are tending to decompose into red iron-ores. Minute round magnetite grains are also present in the base, as well as larger cubical grains.

Name: Pseudospherulitic Biotite-Trachyte.

C.13. Grey Trachyte. Loc.: Johnston's Pinnacle.

Texture: holocrystalline, fine-grained, porphyritic in anorthoclase; base trachytic in fabric.

Composition: felspar forms about 90 % of the rock, and consists of phenocrysts of microcline cryptoperthite, and of anorthoclase; and a second generation of laths of the same mineral, showing marked shadowy extinction. Next in abundance we have ægirine-augite, showing strong pleochroism and almost straight extinction. It occurs both as idiomorphic and allotriomorphic grains. The chief accessory is magnetite in corroded grains of various sizes. Limonite is the most abundant decomposition-product.

Name: Porphyritic Ægirine-Trachyte.

C.28. Trachyte. Loc.: summit of The Pinnacle.

Texture: holocrystalline, porphyritic-hiatal, perpatic, with even-grained trachytic base.

Composition: the felspar, consisting of a few anorthoclase phenocrysts together with the usual prismatic small laths of anorthoclase, forms about 90 %. The rest consists of micropoi-

kilitic aggregates of cossyrite and arfvedsonite, acicular ægirines, ægirine-augite grains, corroded magnetite, red iron-ores, and a few specks of sphene(?).

Name: Porphyritic Soda-Trachyte.

C.21. A somewhat decomposed, otherwise normal, porphyritic, soda-trachyte, containing interstitially some grains of free quartz. Ferrite occurs as an abundant alteration-product of ægirine-augite and soda-amphibole. Loc.: near Bald Knob.

No.X.633. Trachyte-Porphyry. Loc.: The Pinnacle.

Handspecimen: coarsely porphyritic, iron-stained, light-coloured rock.

Texture: holocrystalline; porphyritic, dosemic; with fine-grained trachytic base.

Composition: main constituent felspar. In addition we have 2 % to 3 % of light green augite. The felspar phenocrysts are hypidiomorphic, corroded, and exhibit a shadowy extinction clearly due to ultramicroscopic twinning; frequently this is so marked as to give the appearance of the *gitter*-structure of microcline. Carlsbad twinning is well-marked. The inclusions consist of ægirine-augite and glass. Clearly these phenocrysts consist of microcline microperthite and cryptoperthite. The felspar of the base consists of the usual microlites of tabular and nephilinitoid habit, showing Carlsbad twinning; they consist of soda-sanidine, and give the base an orthophyric-trachytic fabric. The pyroxene is a colourless to light green variety of ægirine-augite, with an extinction angle of 33°.

This rock appears, from field-occurrence, to be the remnant of a sill. Its micro-structure is indicative of hypabyssal origin; for this reason we call it Porphyritic Ægirine-Augite Sölvsbergite.

No.X.648. Trachyte-Porphyry. Loc.: The Pinnacle.

Handspecimen: Miarolitic, coarsely porphyritic rock stained with iron-ores.

Texture: holocrystalline, porphyritic, serial, dosemic; base hypidiomorphic-granular, near orthophyric in fabric.

Composition : essential constituent, felspar; minor constituents, ægirine-augite, magnetite, sagenitic rutile, and secondary chalcedony. The large felspar-phenocrysts consist of microcline microperthite and cryptoperthite, as in X.633. They are often almond-shaped. The smaller phenocrysts are almost idiomorphic, and have the nephilinitoid habit, and the same composition. The corroded almond-shaped phenocrysts have a rim of clear anorthoclase. The base consists of nephilinitoid and lath-shaped microlites of anorthoclase. The next in order of abundance is a brown, non-pleochroic mineral, with concretionary structure, and a very low, yet noticeable, double refraction. This mineral is probably chalcedony stained with limonite, and may represent infilled miarolitic cavities. Limonite (secondary) occurs as strands through the phenocrysts and base alike. Magnetite occurs sparingly as round, corroded, phenocrysts. A few idiomorphic grains of light green ægirine-augite occur in the base. Sagenitic rutile and apatite are often included in the felspar. A little secondary chlorite and serpentine are also present.

Name: a typical Sölvsbergite. This rock occurs also as the plug of The Young Man.

No X.609. Porphyritic Trachyte. Loc.: Bald Hill (?)

Handspecimen : compact, porphyritic, flesh-coloured dyke-rock, with an aphanitic base.

Microscopic texture: holocrystalline; porphyritic hiatal; with micro- to crypto-crystalline trachytic base.

Composition: the essential constituent is felspar (over 90%). This is of two generations. The phenocrysts have two distinct cleavages, parallel to (010) and (001), and a parting parallel to (100). Carlsbad twinning is common; Manebach twinning also occurs; in addition faint albite-twinning is occasionally observed, and, if not, there is marked shadowy extinction due to ultramicroscopic twinning. The crystals are rounded, as in X.648, and have a rim of clear orthoclase. The refractive index is less than that of canada balsam. The habit most commonly observed is the prismatic with bc forming an angle of 88°. The faces

(001), (021), (101) and (201) are apparently best developed. The crystals are optically negative, but yet almost uniaxial in character. The extinction-angle on c (001) varies from 6° to 15° and on *b* (010) from 8° to 10°. Sagenitic rutile is a common inclusion. Evidently this generation consists of microcline cryptoperthite. The felspar of the second generation is the usual anorthoclase. Ægirine and augite are practically absent. Strands of quartz occur interstitially. A brownish-yellow, almost isotropic, titanium-mineral, surrounded by secondary leucoxene, is sparingly present. It is probably perofskite. Tridymite and fluorite both occur as accessories along miarolitic cavities. Brown and red iron-ores, and a little chlorite and kaolin occur as decomposition-products.

Name: Trachytic Quartz-Trachyte-Porphyry, or Quartz-Sölvsbergite.

No.X.619. Trachyte-Porphyry. Loc.: Dyke, Tom Cole's Farm, Parish of Waldegrave.

Handspecimen: compact, coarsely porphyritic rock.

Microscopic texture: as in X.609.

Composition: the constituents in order of decreasing abundance are (1) *essential*, felspar; (2) *minor*, ægirine, quartz, and magnetite, (3) *accessories*, zircon, fluorite; and (4) *secondary*, chalcedony and iron-ores. The felspar phenocrysts are twinned as in X.609. The extinction-angle varies from 3° to 14°. There are two good partings, and two good cleavages at about 97°. Optically negative. Clearly a variety of soda-rich anorthoclase. The usual inclusions are hæmatite, dusty garnet (?), chlorite and zircon. The second generation is also anorthoclase. The ægirine occurs as allotriomorphic corroded crystals, and as idiomorphic grains, decomposing to chlorite and iron-ores. It is highly pleochroic, and has straight extinction. In some cases a reddish-brown mass of primary hæmatite forms the nucleus of a tufty aggregate of ægirine grains. In other cases a micropoikilitic aggregate of hæmatite and felspar is seen. In such cases an original soda-amphibole aggregate has probably been pseudomorphosed into hæmatite and ægirite in the pneumatolytic period of consolidation.

Idiomorphic magnetite grains, often enveloped by secondary hæmatite, are present. Yellowish acmite occasionally forms tufty aggregates. In these a nucleus of brown soda-amphibole (cossyrite) is sometimes seen. Yellowish isotropic material is present, and may be partly glass and partly chalcedony. A few allotriomorphic quartz-grains, and grains of a colourless isotropic mineral with high refractive index are occasionally present interstitially. The latter appears to be fluorite.

The order of consolidation, as worked out from this slice, appears to be,

*1. Zircon
*2. Magnetite
*3. Felspar
*4. Hæmatite
5. Cossyrite?
6. Ægirine
7. Acmite
8. Felspar
9. Quartz
10. Fluor, chalcedony, limonite, hæmatite

Name: Quartz-Acmite-Trachyte-Porphyry.

No.X.624. Porphyritic Trachyte (or Comendite). Loc.: Pilcher's Farm.

Handspecimen: compact, light-coloured, yellowish-grey, porphyritic rock.

Texture: holocrystalline, perpatic, with micro- to cryptocrystalline, trachytic base.

Composition: the main constituent is felspar. The other minerals are acmite, iron-ores, chalcedony, opal, and perhaps a trace of glass. The dominant felspar is the usual anorthoclase. Some corroded phenocrysts have the characters of cloudy orthoclase. One corroded mass appeared to consist of four differently oriented parts, separated by wavy boundary lines; hence it is

* Intratelluric.

composed of four allotriomorphic crystals. Each part abounds in rounded vesicles partly infilled with opal, and contains liquid and gaseous bubbles too. The whole mass is surrounded by a belt of chalcedony. It is interesting because it must represent either an included crystal-aggregate through which magmatic waters dissolved their way, and deposited silica during the period of consolidation of the rock; or it represents the amygdaloidal infilling of a vesicle by a "eutectic" solution of felspar and hydrous silica, giving a micrographic intergrowth. In either case it is a good illustration of the influence of pneumatolytic action (cp.X.649). A fair amount of yellowish acmite, in hypidiomorphic needles, is present; and also reddish iron-ores from decomposition. Tridymite (?) occurs in minute vesicles. Another isotropic colourless substance present is probably hydrous silica.

Name : Trachytic Comendite.

Note : a white rock, with bluish bands and flow-structure, from the same locality is, in handspecimen, studded with large and small vesicles, more or less infilled with white granular minerals.

C.34. Coarse porphyritic Sölvsbergite. Loc.: near The Old Woman.

Texture: holocrystalline; dosemic; the base is very fine-grained and pilotaxitic-stellate.

Composition: the phenocrysts consist of large felspars (up to ½ inch), smaller ægirine-augites, and magnetite. The felspars consist of oligoclase, with multiple twinning and refractive index greater than that of canada balsam, and the usual typical anorthoclase and microcline-microperthite. The ægirine-augite is weakly pleochroic, and extinguishes at 35°. The magnetite is titaniferous, and is accompanied by ilmenite. The base consists of the same minerals, together with secondary limonite.

Name: Oligoclase-Sölvsbergite.

B. *Melanocratic Trachytes, &c.*—These rocks are allied to the dark trachytes which occur in the Warrumbungle Mountains (*e.g.*, Timor Ledges, Nandi Mountain, Naman Ledges, &c.).

C.12. Dark greenish Trachyte. Loc.: Watt's Pinnacle.

Texture: holocrystalline; porphyritic, dopatic; base fine-grained, and pilotaxitic.

Composition: the phenocrysts consist chiefly of microcline-microperthite and anorthoclase, but smaller ones of ægirine-augite and corroded magnetite are also present. The microcline microperthite shows characteristic cross-hatching. The felspar of the base is lath-shaped soda-sanidine. The ægirine-augite occurs in strongly pleochroic, corroded idiomorphs, and also in the base as minute grains and rods. It is developing a uralitic cleavage.

Name: Pilotaxitic Ægirine-Trachyte.

C.23. Greenish Trachyte. Loc.: east of Bald Knob.

Texture: holocrystalline; porphyritic, trachytic with well marked flow-structure.

Composition: felspar forms about 80% of the rock; ægirine-augite about 15%; magnetite and other constituents about 5%. These minerals have the same characters as in C.12. The felspar and pyroxene crystallised together throughout, and hence mutually interfere with one another's crystallographic development. Secondary limonite and hæmatite are present.

Name: Trachytic Ægirine-Trachyte.

Note: the difference between melanocratic trachytes (such as C.12 and C.23) and leucocratic trachytes (such as X.631, C.13, C.28) lies neither in texture, nor in the nature of the contained minerals, but in the greater abundance of ægirine and magnetite in the former type, whereby it acquires its darker colour.

C.8. Dark green aphanitic Trachyte. Loc.: Cox's Gully, south of The Old Man.

Texture: holo- or hypocrystalline; porphyritic, perpatic; base, very fine, microcystalline, even-grained, trachytic.

Composition: the felspar phenocrysts are strongly resorbed at the edges, and are traversed by cracks filled with katapleiite. Some consist of anorthoclase, others of microcline-microperthite. They occasionally include biotite. Idiomorphic magnetite occurs

in grains larger than those of the minerals of the base. The base consists of minute felspar-laths, magnetite-granules, and isotropic dark glass. In addition, this rock contains several large, six-sided, corroded masses of a yellowish colour. They seem to possess a fair cleavage, and faint pleochroism. They appear brownish by reflected light, and have an extremely high double refraction and refractive index. The extinction is shadowy, black crosses forming much the same as where crystals overlap; this feature appears to be due to a twinning lamellation. The mineral is probably a form of rutile. Nepheline may be present in the base, but has not been determined with certainty.

Name: Phonolitic Rutile (?) Trachyte.

C.26. Dark (almost black) Trachy-andesite, aphanitic in hand-specimen. Loc.: north side of Pinnacle.

Texture: porphyritic, perpatic with microcrystalline to hemi-hyaline trachytic base.

Composition: the phenocrysts consist of plagioclase varying from albite to acid andesine. The felspar of the base consists of minute lath-shaped microlites. The pyroxene consists of minute ægirine-augite laths, and grains of colourless diopside. Sphene occurs in minute rods, and magnetite in very small rounded grains. Interstitial dark glass is present. In addition, we have, in this rock, fragments of phenocrysts of *astrophyllite*, with ragged ends and typical micaceous cleavage, and a few phenocrysts of apatite. This rock appears to be a basic facies of alkaline-trachyte.

Name: Astrophyllite-bearing Trachy-Andesite.

No.X.363. Phonolitic Trachyte. Loc.: Pinnacle Road.

Handspecimen: dark, very fine-grained, aphanitic.

Texture: holocrystalline, very fine-grained, pilotaxitic.

Composition: felspar, pyroxene, sphene, magnetite, kataphorite, katapleiite and nepheline. The felspar is of two generations: (1) phenocrysts consisting of anorthoclase and microcline-microperthite, almond-shaped in outline and surrounded by a corrosion-rim, and studded with inclusions of diopside and greenish augite.

They have an extinction-angle of 8°. (2) The felspar of the base is microlitic soda-sanidine. Strands of katapleiite penetrate the phenocrysts and base alike. The pyroxene consists of phenocrysts of yellowish-green, pleochroic ægirine-augite, with extinction-angle=38°, and minute bluish, greenish, to colourless rods of ægirine-augite in the base. Sphene occurs in the base as minute lozenge-shaped prisms surrounded by leucoxene. Grains of magnetite are abundant. A few idiomorphic, corroded, nepheline phenocrysts were observed. Eucryptite(?) occurs in some of the felspar phenocrysts. A couple of poikilitic aggregates of kataphorite, with pleochroism from red to dull brown and bluish-green, occur in parts of the slide.

Name : Pilotaxitic Trachy-Phonolite.

Magmatic name : Judithose, near Laurdalose(see Analysis v.).

No.X636. Trachyte-Porphyry. Loc.: Norris's Farm, Spring Creek.

Handspecimen : compact, bluish-grey rock.

Texture: holocrystalline, porphyritic, with fine grained trachytic base.

Composition : the phenocrysts of felspar consist of microcline cryptoperthite; they are allotriomorphic, and have a zone of inclusions just within the border. The inclusions consist of ægirine-augite, magnetite, zircon, and sagenitic rutile. A second growth of clear felspar has been deposited round this zone. The felspar microlites of the base have the properties of sanidine. The pyroxene phenocrysts are yellowish-green, and have an extinction angle of 27-28°. They consist of ægirine-augite. The finer, acicular microlites of the base are grass-green, and have an extinction of 18°, and are therefore more closely allied to true ægirine. Strands of katapleiite are developed in the felspar phenocrysts. Some minute yellow rods of laavenite are included in the felspar and occur also in the base. A little felspathoid is probably present in the base.

Name : Phonolitic Trachyte-Porphyry.

No.X.639. Trachyte-Porphyry. Loc.: east side of The Old Man.

Handspecimen: a reddish rock containing large, black, iridescent, irregularly cracked phenocrysts, and felspar phenocrysts, some of which are vesicular, others quite pumiceous.

Texture: holocrystalline, porphyritic, with even-grained hypidiomorphic, granular base.

Composition: the base consists essentially of untwinned nephilinitoid and prismatic felspar, decomposing to kaolin. The felspar phenocrysts are of three kinds: (1) a clear glassy sanidine; (2) a moirée microperthite, with patchy extinction; and (3) a basic labradorite. All these are broken, and surrounded with a corrosion-rim, round which a zone of orthoclase of the second generation appears.

The dark mineral is hæmatite, which has often a nucleus of magnetite, and a rim of limonite. Leucoxene occurs as a decomposition-product, indicating that the magnetite is titaniferous.

Name: the magma from which this is derived is a mixture of the typical trachytic and typical andesitic. The vesicular phenocrysts and pumiceous aggregates indicate that, after the formation of the phenocrysts, magmatic vapours, charged with acids, penetrated and leached the phenocrysts, perhaps at the same time altering magnetite to limonite.

c. *The Andesites.* The dominant type of andesite is that met with on The Old Man.

No.X.634. Black, vesicular, porphyritic Andesite. Loc.: Top of The Old Man.

Texture: holocrystalline; porphyritic, hiatal; hyalopilitic base.

Composition: the constituents are felspar, augite, ilmenite, magnetite, and glass. The phaneric felspars are twinned on the Carlsbad, Albite, and Pericline laws; zoning is frequently observed; refractive index higher than that of canada balsam; and extinction-angle 15° to 20°. The microlites of the base have apparently the same composition. This constituent is, therefore, an andesine or acid labradorite. The augite occurs in small,

usually idiomorphic, but slightly corroded, phenocrysts. It is colourless, non-pleochroic, and has an extinction-angle ($c' : c$) of 32°. It is neatly twinned, with (100) as twinning plane. $Bx_a = c$. Optically +. Apparently it is a variety of diopside. Olivine is absent, but ilmenite occurs as small crystals. The base consists of minute, felspar needles, dusty magnetite, and glass.

Order of consolidation.

1. Ilmenite ————————
2. Augite ————————
3. Felspar phenocrysts ————————
4. Felspar microlites ————————
5. Magnetite ————————
6. Glass ————————

Name: Augite-Andesite.

No X.632. Compact black Porphyritic Andesite. Loc.: Hopetoun Waterfall.

Texture: holocrystalline; porphyritic, hiatal; with microcrystalline, pilotaxitic base.

Composition: the chief constituents are felspar of two generations, augite, a little olivine, and titaniferous magnetite. The felspar phenocrysts are beautifully zoned, varying in composition from oligoclase on the rim, to basic andesine or labradorite in the centre. Their other characters are as in .634. In addition they are often extremely corroded, and contain inclusions of augite and chlorite. The microlitic felspar has the properties of albite. Interstitial orthoclase also occurs. Augite does not show as phenocrysts, but it is abundant as idiomorphic, faintly purple, grains in the base, changing to chlorite and chloritoid. Titaniferous magnetite is abundant; a little ilmenite also occurs. Olivine is sparingly present, as corroded phenocrysts, wholly or partly altered to serpentine.

Name: Olivine-Andesite.

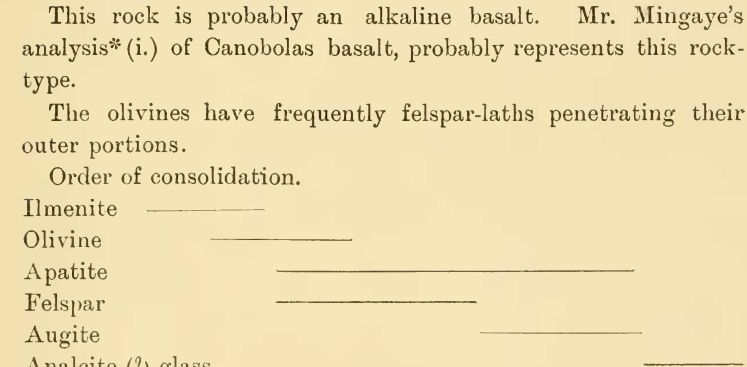
D. *The Basalts.* There are two types, the common olivine-basalts, and olivine-fayalite-melilite basalts.

The former type is represented by a slide of a black-grained basalt from Norris's Farm, The Canobolas. The felspar forms about 65%, and occurs as laths, varying in composition from albite to acid labradorite. Augite, of a brown to puce colour, in rounded allotrimorphic grains, and its decomposition-product, chlorite, occur to the extent of about 15%. Olivine alone occurs as phenocrysts; it is decomposing to serpentine. Small red, rounded grains of fayalite are also present. These peridotic constituents form about 10%. Ilmenite forms about 7%. The balance consists of an isotropic, light-coloured residuum, probably containing analcite, and apatite needles which penetrate the felspars and base alike.

This rock is probably an alkaline basalt. Mr. Mingaye's analysis* (i.) of Canobolas basalt, probably represents this rock-type.

The olivines have frequently felspar-laths penetrating their outer portions.

Order of consolidation.



This rock is a hyalopilitic olivine-analcite (?) basalt.

The Melilite Basalts.—The basalt from the Racecourse Quarry, near Orange, is a dark rock of typical basaltic appearance.

Texture: holocrystalline; fine and even-grained, with pilotaxitic-ophitic fabric.

Constituents (in order of decreasing abundance): felspar, augite, olivine, melilite, ilmenite, magnetite, and accessory apatite. The prismatic microlites of felspar penetrate the augite grains ophitically, and form frames round the augite, giving *microtine*

* Records Geol. Surv. N.S.Wales, 1904, Vol. vii.

structure. They are twinned on the Carlsbad and Albite laws, and have the properties of andesine. Allotriomorphic orthoclase, with shadowy extinction, seems also to be present in minute amount. The augite, in hypidiomorphic crystals, is a brownish, titaniferous variety, with extinction angle 45°. Colourless olivine occurs also in hypidiomorphic grains. A little red fayalite, ragged plates of ilmenite, and idiomorphic magnetite grains (titaniferous) are all present. Chlorite and red iron-ores occur as decomposition-products. In addition, we have some isotropic, or nearly isotropic, colourless to yellowish-green minerals lying interstitially. The chief of these has a characteristic peg-structure, indicating that it is melilite. The pegs consist of apatite, and magnetite grains are also abundantly included. As the pegs in melilite lie perpendicular to the basal plane, it is found that the mineral under discussion, if it be melilite, has a perpendicular to the C crystallographic axis, and is optically negative ($Bx = a$). The R.I. is medium, and its D.R. very low. Shape always allotriomorphic.

Another totally isotropic, colourless constituent, probably analcite, is also present.

Order of Consolidation.

1. Ilmenite
2. Olivine
3. Augite
4. Felspar
5. Magnetite
6. Apatite
7. Melilite(?)
8. Glass (analcite?)

Name: Ophitic Olivine-Melilite Basalt.

Note.—The rocks indicated by the letter X., followed by a reference number, belong to the Technical College Collection gathered together by Mr. Süssmilch on several visits. Those indicated by the letter C, belong to my own collection (H.I.J.).

ANALYSES.

	i. Basalt, Canobolas, by J. C. H. Mingaye.	v. Phonolitic Trachyte X.363. H. I. Jensen.	vi. Comendite X.608. H. I. Jensen.	vii. Comendite — B. White.
SiO_2	48·92	57·39	69·23	72·06
Al_2O_3	14·87	16·88	14·58	13·86
Fe_2O_3	3·99	1·09	2·54	1·90
FeO	7·44	6·10	0·67	1·71
MgO	5·73	1·01	0·30	0·19
CaO	7·26	3·16	0·44	0·18
Na_2O	3·42	6·71†	6·82	5·84
K_2O	1·80	5·86†	3·95	3·69
$H_2O(100°+)$	0·82	0·11	0·94	0·21
$H_2O(100°-)$	1·56	0·49		0·33
CO_2	0·09	u.d.	—	0·03
TiO_2	2·78	1·11	0·13	0·12
P_2O_5	0·59	—	--	0·06
SO_3	0·08	—	—	—
Cr_2O_3	0·01	—	—	—
NiO	0·04	0·04	0·05	abs.
MnO	0·29	0·05	tr.	0·07
BaO	0·04	—	—	—
V_2O_3	0·02	—	—	—
CuO	0·06	—	—	—
Sum ...	99·83	100·00	99·65	100·25

General Remarks.—From the foregoing petrological sketches it is clear that the Canobolas area is an alkaline petrological province. The minerals characteristic of each rock-division represented here are, generally speaking, the same as those met with in the Nandewar and Warrumbungle rocks.

The rock-types vary from the very acid comendites and pantellarites, to basic melilite-basalts, but all are derived from a magma extremely rich in Al_2O_3, TiO_2, and Na_2O.

† Owing to loss of mixed alkali by spurting, the total alkali was estimated by difference, and divided between K_2O and Na_2O in the experimentally determined ratio.

In many of the rocks the evidences of the solvent and mineralising powers of circulating acid vapours in the period of consolidation are well marked. The miarolitic nature of the plugs and dykes is also indicative that the magma was very hydrous.

In many of the comendites, quartz is not visible, but it exists nevertheless in the base in the form of opal or chalcedony, and tridymite.

The sequence is the same as in the Warrumbungles. The basic andesites cover the highest summits, and the basalts were erupted last, apparently from fissures intersecting the country surrounding the central area.

Many rare minerals have been identified in small amounts with considerable certainty. They comprise melilite, fayalite, astrophyllite, perofskite, wöhlerite, laavenite, kataphorite, and cossyrite(?).

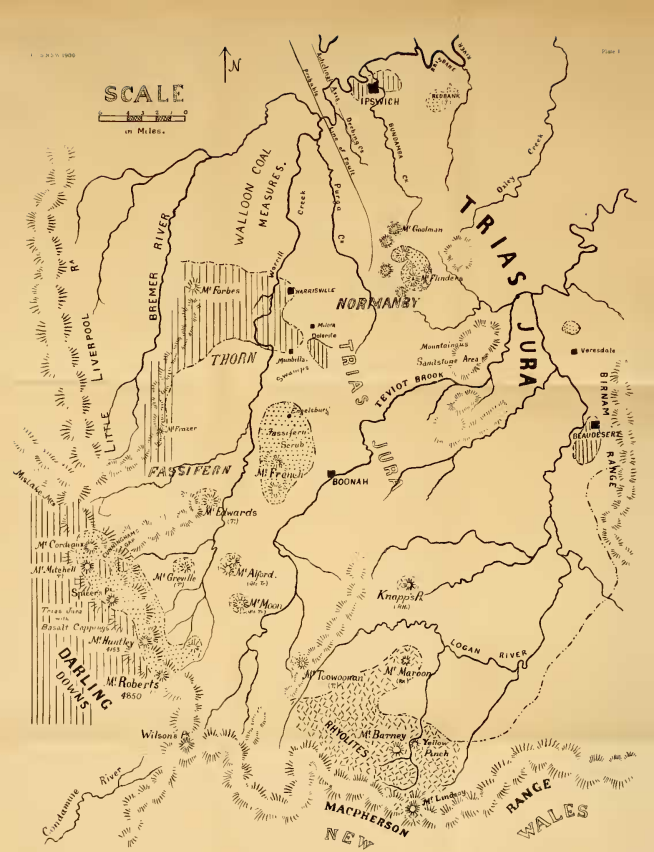
Some of the rocks described take a beautiful polish and would make excellent and most durable building-stones.

No basic tuffs, lamprophyres or basic dyke- and sill-rocks have been met with. The clastic and hypabyssal rocks all belong to the leucocratic and melanocratic *trachyte* series.

General Note.—The volcanic rocks rest in this area on a peneplain, having an altitude of about 3000 feet The basalts were erupted in some cases after the uplift and cañon-formation of the present cycle of erosion.

It has been shown by one of us (H. I. Jensen) that the Nandewar lava-flows to the west of Mt. Lindesay rest on the sandstone at an altitude of 1,800 to 2,000 feet. To the east of Mt. Lindesay and of a line running through it in a N.N.W.-S.S.E. direction, the lavas commonly have an altitude of 3,000 feet. Between the mountain-region and Narrabri the mesas average about 1,400 feet in altitude. It was shown that these discrepancies in the altitude of the peneplain are probably caused by a fold (monoclinal) due to the uplift of the New England segment, and subsidence of the earth-segment to the west, and further uplifts due to intrusions of igneous rock. This was followed by the extrusion of lavas, and subsequently step-faulting

[Printed off July 9th, 1909.]



Map of the Mt Flinders & Fassifern Districts Qld.

Legend. Trachytes Basalts Rhyolites

[Printed off July 9th, 1909.]